COASTAL MIXING

Eric A. D'Asaro
Applied Physics Laboratory
University of Washington
1013 NE 40th Str
Seattle, WA 98105
Phone: (206) 685 2982 fax: (206) 543 6785 email: dasaro@apl.washington.edu
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LONG TERM GOALS

I seek to understand the mechanisms of turbulence and mixing in shallow water sufficiently well to be able to specify useful parameterizations for coastal circulation models.

OBJECTIVES

I believe that this goal can best be achieved through a combination of comprehensive measurement of the turbulent fluctuations, the larger scale flows which drive them and modelling. These turbulent flows are often complex and rapidly changing and can be only properly measured using a combination of methods which measure a variety of spatial and temporal scales. My medium-term scientific objective is to make and analyze such measurements in cooperation with other investigators.

APPROACH

My technical approach is to combine neutrally buoyant Lagrangian floats, acoustic remote sensing of various types, microstructure measurements and rapid CTD profiling. This instrumental suite can both map a given flow and determine its mixing rates.

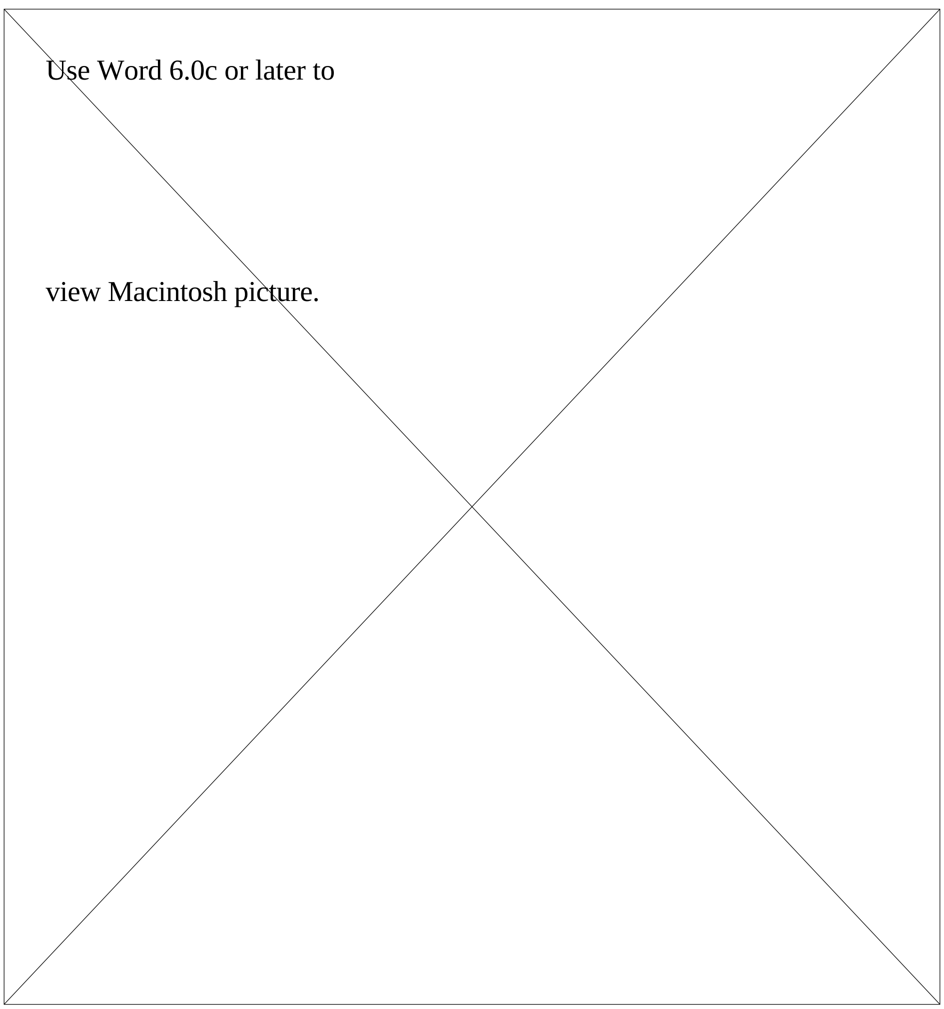
During the last few years, I have developed a new type of neutrally buoyant float (see image on right) designed to be used in energetic turbulent flows such as those found in the top and bottom boundary layers of the ocean. A combination of accurate ballasting, a compressibility matched to that of seawater and high drag is used to make these floats follow the motion of water parcels accurately. The floats measure their depth and are acoustically tracked in the horizontal and thus produce measurements of vertical and horizontal velocity. They measure the temperature and vertical vorticity (from spin rate) of the water surrounding them. We have made about 250 deployments of these floats, in a wide variety of turbulent coastal and open ocean environments.

Lagrangian Float

WORK COMPLETED

A major task over the past few years has been to evaluate the accuracy of the floats and understand their behavior in homogeneous turbulent flows. A paper describing the floats, their accuracy, and some of the analysis methods has been published in the *Journal of Atmospheric and Oceanic Technology*. A second paper, describing in detail the Lagrangian spectra of vertical velocity and vorticity in high Reynolds number turbulence and explaining it using concepts from homogeneous turbulence theory has been submitted to the *Journal of Fluid Mechanics*. We find good agreement between the theory and our observations of acceleration spectrum. The vorticity spectra agree only at low frequency; we conclude that we do not understand the what controls the high frequency fluctuations in float rotation rate. Our major result is***:* the large-eddy-frequency and turbulent kinetic energy dissipation rate of a turbulent flow can be determined by Lagrangian floats as long as the overturning scale of the flow is larger than the float.**

The major task in FY97 been to use the Lagrangian floats to help understand turbulence in a density stratified environment. Here, both internal waves and turbulence can exist and it is often difficult to separate them. We find that **internal waves can be separated from turbulence based on Lagrangian frequency** as shown in Fig. 1. Here, average spectra



of vertical (W) and horizontal (U,V) velocity measured by floats from strongly mixing but stratified environments (mostly in Knight Inlet) are plotted vrs frequency. For $\omega > N$ (right of the dashed vertical line) the data are consistent with **turbulence**: the velocity is nearly *isotropic* since the three components have similar energy, and the spectral slope is -2, as we have found for the ***inertial subrange*** of unstratified turbulence. For $\omega < N$ (left of the dashed vertical line) the data are consistent with **internal waves**: the velocity is highly *anisotropic*, there is more horizontal kinetic energy than vertical, and the ratio of vertical to horizontal energy varies with frequency in agreement with the usual ***consistancy relation*** for internal waves. Furthermore, the W spectrum is white, while the (U,V) spectra have a -2 slope as found in the *Garrett-Munk spectrum*.

The form of these spectra imply a **new parameterization** for stratified turbulence relating the energy in the waves and the turbulent mixing rate. For sufficiently energetic flows we find $e = w^2 N$; the rate of kinetic energy dissipation, ε, is proportional to the mean vertical kinetic energy in the waves and the stratification N. This should apply for internal wave fields about 10-20 times more energetic than the open ocean Garrett-Munk levels. Such mixing rates are not uncommon in the Littoral zone.

RESULTS

1.. Lagrangian velocity spectra in stratified flows can separate the energy of internal waves (frequencies less than N) from that of turbulence (frequencies greater than N).

2. All of the anisotropy in stratified turbulence appears to be due to internal waves, the turbulence remains isotropic.

3. The matching of these two regimes at N implies a new parameterization of internal wave driven mixing in which the kinetic energy dissipation rate is proportional to the internal wave vertical kinetic energy times N.

4. This parameterization should be appropriate for energetic shallow water regimes.

IMPACT FOR SCIENCE

Accurate models of internal waves and turbulence are crucial for modelling shallow water circulations. Proper distinction between waves and turbulence is crucial for making such models as are parameterizations of these processes.

TRANSITIONS

None

RELATED PROJECTS

These floats are close relatives of those used to study deep convection in the Labrador Sea funded by ONR 322OM. Much of the data used here came from measurements in Knight Inlet as part of an ONR322PO study of solibores. Mixing processes in these various environments are similar in many ways and we learn the most by comparing and contrasting them.

REFERENCES

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Lagrangian Frequency Spectra of Vertical Velocity and Vorticity in High Reynolds' Number Oceanic Turbulence, submitted to *J. Fluid Mechanic,* 16 pp

Web site for Knight Inlet measurements
http://pinger.ios.bc.ca:80/cruises/knight95/start.html